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DIETARY PARTITIONING AND FORAGE ALLOCATION ON DESERT RANGELANDS

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INTRODUCTION

Livestock and wild herbivores convert forage resources unuseable by man into high quality protein. Maximization of protein yields from forage resources requires understanding of forage availability and herbivore dietary habits. Knowledge of dietary preferences permits managers to select a mixture of grazers that optimizes forage harvest without significant interspecific competition or abuse of the forage resource.

Winter and early spring dietary habits of four major herbivores of the Great Basin area, cattle (*Bos taurus*), sheep (*Ovis aries*), pronghorn (*Antilocapra americana*), and black-tailed jackrabbits (*Lepus californicus*) were investigated at the Desert Experimental Range (U.S. Forest Service) in southwestern Utah from December 1981 through April 1982. The goal of this investigation was to document winter and early spring dietary partitioning between these herbivores on a cold desert shrub range typical of much of the Great Basin Desert rangelands. Researchers have predicted potential competition between these sympatric herbivores is greatest during the winter-spring bottleneck (Clary and Holmgren 1981, Severson and May 1967, Currie and Goodwin 1966, Hoover et al. 1959, Buchner 1950). The investigation used microhistological analysis of herbivore feces and vegetation sampling to estimate forage availability, calculate forage preference, quantify dietary overlap, and evaluate potential competition. A new system of forage allocation based on AUE's derived from degree of dietary overlap is presented. This strategy will allow more precise management of forage resources.

STUDY AREA

The Desert Experimental Range (DER), in Millard County, southwestern Utah, was selected as the study area. The DER consists of 225 km of rangeland considered typical of the 16 million hectares of low salt desert shrub type of the Great Basin and surrounding areas (Clary and Holmgren 1981) and has been described in detail by Holmgren and Hutchings (1972), Holmgren and Brewster (1972), and Holmgren (1974). Units 1 and 2 of allotment number 3, covering approximately 10 km^2, were chosen as winter and early spring study sites respectively. The allotment lies within the black sagebrush-shadscale-grass vegetation type classified by Hutchings and Stewart (1953).

Soils are predominantly Aridisols and Entisols, loams and sandy loams, with an average pH of 8.0. Elevation ranges from 1,547 to 2,565 m. Nearly 75% of the area is alluvial slope or flat valley bottom; steep rockland overlain with shallow soils constitutes the remainder. Estimated average annual precipitation is 10 to 20 cm, the majority being snow. Growing season is more moisture than temperature dependent. Temperature extremes vary widely (Holmgren and Hutchings 1972).

Shrubs and half-shrubs dominate the area. Common shrubs are black sagebrush (<u>Artemisia nova</u>), bud sagebrush (<u>Artemisia spinescens</u>), winterfat (<u>Eurotia lanata</u>), shadscale (<u>Atriplex confertifolia</u>), and Greene rabbitbrush (<u>Chrysothamnus greenei</u>). Warm and cool season grasses include galleta grass (<u>Hilaria jamesii</u>), sand drop seed (<u>Sporobolus cryptandrus</u>), blue gramma (<u>Bouteloua gracilis</u>), Indian ricegrass (<u>Oryzopsis hymeniodes</u>), squirreltail grass (<u>Sitanion hystrix</u>), and cheatgrass (<u>Bromus tectorum</u>). Forb species including

Russian thistle (Salsola iberica), halogeton (Halogeton glomeratus), and hoary aster (Machaeranthera canescens) are considerably less abundant (Holmgren and Brewster 1972).

Herbage production and carrying capacity are relatively low. Ground cover by live vegetation averages 5 to 15% (Holmgren and Hutchings 1972). No naturally occuring free water is available. Livestock and game depend on water tanks.

Viable free roaming populations of black-tailed jackrabbits and pronghorn inhabit both units of the allotment. Ten cattle grazed unit 1 from December 1981 until late March 1982, when they were moved to unit 2 and remained until early May. All were mature gestating females. Approximately 2,000 sheep, the majority gestating ewes, grazed units 1 and 2 during December 1981 and April 1982 respectively.

METHODS

Vegetation Sampling

Unit 1

Dry biomass of the remaining previous year's growth was estimated for each plant species in unit 1 from mid December 1981 through early March 1982 by double sampling and linear regression (Uresk et al. 1977). Shrub production was determined by stratified random sampling and linear regression. Two strata, delineated by aspect and subsample unit size (Cochran 1977), were sampled with 29 and 9 transects each with 5 circular plots of 20 m^2 and 50 m^2 respectively. Plot centers were located 25 m apart along north-south transect lines. Production was estimated by expanding a linear regression method described by Green and Flinders (1980). Within each plot all shrub species were measured and the following data recorded: (1) species; (2) longest

diameter of canopy; (3) longest diameter of canopy at right angles to dimension (2); (4) average canopy depth; (5) maximum shrub height; and (6) occular estimate of percent live portion of the shrub canopy. Approximately 20 shrubs of each major species were subjectively chosen to represent the range of size observed. These shrubs were measured and all remaining previous year's growth clipped, oven dried, and weighed. Where applicable, shrub measurements were combined to describe ellipsiodal volumes, and used with dry weights to develop the regression equations in Table 1. The correlation of each equation is significant at $p<0.01$.

Remaining previous year's grass and forb production was estimated by double sampling and linear regression of plants found in each of 18 statified random transects comprised of five 20 m^2 circular plots placed at 25 m intervals along north-south transect lines. Clipped grasses and forbs were oven dried and appropriate dry weight correction factors computed.

Unit 2

Current spring growth of grasses, forbs, and shrubs in unit 2 was estimated from late March through April 1982 by double sampling and linear regression. Grasses and forbs were measured in 35 random transects comprised of ten 0.89 m^2 circular plots placed 10 m apart along north-south transect lines. Clipped grasses and forbs were oven dried and used to calculate dry weight correction factors for each species.

Current annual shrub production, was estimated using the weight estimate method of double sampling (Pechanec and Pickford 1937, Tadmor et al 1975) from 9 random transects comprised of five 20 m^2 circular

plots placed at 25 m intervals. Current annual growth from clipped shrubs was oven dried and weighed to determine dry weight correction factors.

Dietary Determination

Diets of sheep, cattle, pronghorn, and jackrabbits were determined by microhistological analysis of fecal samples (Hansen et al. 1978, Hansen and Flinders 1969, Sparks and Malechek 1968). Although differential digestion may cause biased representation of some plant species, dietary trends and relative importance are accurate (Vavra et al. 1978). Bias was assumed constant.

Fecal samples were collected by grab sampling concurrent with vegetation sampling in each unit. Approximately 2 g of fresh material from each of 5 defecations constituted a composite sample. Twenty composite samples were collected from each herbivore in unit 1. In unit 2, twenty composite samples were collected from cattle, sheep, and pronghorns. Black-tailed jackrabbits had to be killed in order to obtain fresh fecal material from colons. Due to leporid scarcity and lack of snow, only 4 jackrabbit colon samples were obtained. Precisely one year later, 10 additional jackrabbit colon fecal samples were obtained from unit 2. Comparison of data from these two sample periods is explained in the results.

Fecal samples were frozen, oven-dried, partially ground in a Wiley Mill over a 20 mesh screen, homogenized, washed over a 200 mesh screen, and mounted with Naphrax high resolution diatom mountant. Five microscope slides were prepared from each composite sample. Material was sufficient to produce at least 20 identifiable plant epidermal fragments per slide (Holechek and Vavra 1981). Twenty

locations on each slide were selected by stratified random methods and the frequency of plant epidermal fragments occuring within the field of view at 100 power magnification was recorded by species. Thus 2,000 locations were examined for each herbivore at both times except jackrabbits during the second sampling period, which were examined by 1,400 locations. Percent frequency of plant fragments was converted to mean particle density (Fracker and Brischle 1944) and ultimately relative particle density (Sparks and Malechek 1968).

RESULTS

Forage Availability

Total remaining previous year's growth on unit 1 was 84.9 kg/ha. Table 2 presents mean kg/ha production and 90% confidence intervals for all plants found in unit 1 sampling. Grasses contributed 27.45 kg/ha, forbs 3.44 kg/ha, and shrubs 54.01 kg/ha. Dominant species and their percent of total production were *Gutierrezia sarothrae* 27%, *Oryzopsis hymenoides* 14%, *Artemisia nova* 12%, *Atriplex confertifolia* 11%, *Bouteloua gracilis* 6%, and *Stipa comata* 6%. These 6 species accounted for over 75% of available forage in unit 1 during the winter months.

Current spring growth of unit 2 was 243.93 kg/ha. Table 3 presents mean kg/ha forage production and 90% confidence intervals for all plant species found in unit 2 sampling. Grasses contributed 49.51 kg/ha, forbs 12.16 kg/ha, and shrubs 182.26 kg/ha. Dominant species and their percent contribution to total production were *Ephedra nevadensis* 19%, *Atriplex confertifolia* 18%, *Gutierrezia sarothrae* 15%, *Artemisia nova* 8%, *Stipa comata* 5%, *Oryzopsis hymenoides* 4%, and *Sporobolus cryptandrus* 4%. These 7 species accounted for over 70% of

available forage in unit 2 during the early spring.

Diets

Diets, assessed by relative particle densities of plant fragments found in the feces of the four herbivores, are presented in Tables 4 and 5 for winter and early spring sampling respectively.

Percent of diet was determined within 10% of the mean at the 90% confidence level for species constituting more than 30% of the diet, within 10% of the mean at the 80% confidence level for species comprising 20-29% of the diet, within 20% of the mean at the 90% confidence level for species comprising 10-19% of the diet, within 30% of the mean at the 90% confidence level for species constituting 5-9% of the diet, and within 30% of the mean at the 80% confidence level for species comprising less than 5% of the diet (Holechek and Vavra 1981).

Winter

One major species, (20% or more of diet) *Oryzopsis hymenoides*, and two minor species (5-19% of diet), *Stipa comata* and *Sitanion hystrix*, made up 86% of cattle diets in unit 1. Two major species, *Oryzopsis hymenoides* and *Artemisia nova*, and two minor species, *Stipa comata* and *Eurotia lanata*, comprised 77% of sheep winter diets in unit 1. One major species, *Artemisia nova*, comprised 93% of pronghorn diets. Jackrabbit diets contained one major species, *Eurotia lanata*, and five minor species; *Forsellesia nevadensis*, *Macheranthera grindelioides*, *Artemisia nova*, *Atriplex confertifolia*, and *Bromus tectorum*, comprising 74% of the diet, with numerous trace species (less than 5% of diet) included in the remainder.

Spring

Increased grass utilization was the general trend among sheep, pronghorn, and jackrabbits from winter to spring. Data from cattle on unit 2 showed one major species, Oryzopsis hymenoides, and two minor species, Sporobolus cryptandrus and Stipa comata, comprising 82% of the diet. Seventy-one percent of the sheep diet was composed of one major species, Oryzopsis hymenoides, and three minor species, Artemisia nova, Atriplex confertifolia, and Stipa comata. One major species, Artemisia nova, and one minor species, Macheranthera grindelioides, accounted for 88% of pronghorn diets.

Jackrabbit dietary data from April 1982 sampling were compared with data from jackrabbits collected in April 1983. A paired t-test was used to detect differences between the total spring diets of each year. No differences were observed. The Mann-Whitney test was used to evaluate differences in the utilization of each plant species in the diets between the two years. Only one significant difference ($p<0.02$) was detected in one trace species, Poa secunda, which comprised 2% of the diet. A major dietary item, Oryzopsis hymenoides tended to differ, but not significantly ($p=0.14$). Because the trends and relative importance of dietary items observed in the 1983 data match those of the 1982 dietary data, this difference was deemed inconsequential and the data from both years were combined for analysis.

Comparison of percent similarity of jackrabbit and other herbivore diets showed no significant differences resulted when similarity indices were calculated by either jackrabbit data set. Two major species, Bromus tectorum and Oryzopsis hymenoides, constituted 79% of jackrabbit diets.

Preference Indices

Although used for many years, the accuracy of preference indices as expressions of true diet preference is now soundly criticized (Loehle and Rittenhouse 1982). Factors including range heterogeneity, plant accessibility, slope, nearness of water, herbivore micro-habitat selection, and presence of rare plant species may combine to diminish the accuracy of preference ratings. Virtually all of these factors were pronounced and influential on the DER study sites.

Loehle and Rittenhouse (1982) reported that all of the preference indices commonly used had serious shortcomings for purposes of accurately representing the concept of dietary preference and are of questionable value in explaining dietary data. The forage ratio model of preference, (% of species A in diet)/(% of species A in habitat), commonly used in range work, (Krueger 1972, Cock 1978), is described as defficient in several areas. Most problematic is the occurrence of plant species in the herbivore diets which, due to rarity or pronounced range heterogeneity, were not encountered, or very rarely encountered, in vegetation sampling. Preference values for species never encountered in vegetation sampling approach infinity, while those for species very rarely encountered become inordinately large. No statistical conclusions can be justifiably drawn from such rare species (Loehle and Rittenhouse 1982). Because of their widespread use in range work, despite these problems, preference indices calculated by the forage ratio model are presented in Tables 6 and 7 for winter and spring respectively. They should be evaluated in light of the limitations discussed above.

A slightly improved index, referred to by Loehle and Rittenhouse (1982) as preference availability, is the relative preference component, (forage ratio index for species A)/(sum of forage ratio indices), of a predictive dietary model proposed by Ellis et al. (1976). Tables 8 and 9 present relative preference indices derived from the preference-availability model of Ellis for all forage species consumed in winter and early spring respectively.

Examination of means and confidence intervals for previous year's growth presented in Tables 2 and 3 together with Tables 8 and 9 shows that several of the preferred plant species were sufficiently rare in the sample to be subject to the limitations warned of by Loehle and Rittenhouse (1982) and therefore suspect. In the following summary of winter and early spring dietary preference, preferred plant species with confidence intervals greater than their mean previous year's growth or with mean previous year's growth less than 0.01 kg/ha, will be denoted by the parenthetical "(highly suspect)," preferred plants with confidence intervals equal to their mean previous year's growth will be denoted by the parenthetical "(suspect)," and preferred plants with mean previous year's growth less than .1 kg/ha will be denoted by the parenthetical "(slightly suspect)."

Winter

Table 8, containing preference-availability indices for winter grazing, shows cattle preferred, in descending order, Sporobolus crytandrus, Orizopsis hymenoides, Sitanion hystrix, Stipa comata, Eurotia lanata, and Hilaria jamesii. Sheep preference in descending order was Macaranthera grindeliodes (highly suspect), Eurotia lanata, Sporobolus cryptandrus, Orizopsis hymenoides, Stipa comata, Hilaria

jamesii, Artemisia nova, Petradoria pumilia (highly suspect), Sitanion hystrix, and Bouteloua gracilis. Pronghorn preferred, in decreasing order, Macaranthera grindeliodes (highly suspect), Prunus fasiculata, Artemisia nova, and Cercocarpus intricatus. Jackrabbits preferred, in decreasing order, Castilleja chromosa (highly suspect), Bromus tectorum (suspect), Macaranthera grindeliodes (highly suspect), Leptodactylon pungens (slightly suspect), Eurotia lanata, Forsellesia nevadensis, Prunus fasiculata, Artemisia spinescens, Artemisia frigida, and Petradoria pumilia (highly suspect).

Spring

From Table 9, spring cattle preference in descending order was Sitanion hystrix (slightly suspect), Eurotia lanata (slightly suspect), Poa secunda, Orizopsis hymenoides, Sporobolus cryptandrus, Stipa comata, and Hilaria jamesii. Sheep preference in decreasing order was Castilleja chromosa (highly suspect), Sitanion hystrix (slightly suspect), Eurotia lanata (slightly suspect), Sphaeralcea grossulariifolia, Orizopsis hymenoides, Poa secunda, Macaranthera grindeliodes, Artemisia spinescens, and Cryptantha spp. Pronghorn preference in decreasing order was Arabis lignifera (slightly suspect), Sphaeralcea grossulariifolia, Macaranthera grindeliodes, Artemisia nova, Poa secunda, Bromus tectorum, Forsellesia nevadensis (highly suspect), and Petradoria pumilia. Jackrabbit preference in descending order was Bromus tectorum, Sitanion hystrix (slightly suspect), Sphaeralcea grossulariifolia, Oenothera caespitosa, Poa secunda, Macaranthera grindeliodes, and Orizopsis hymenoides.

Dietary Overlap

Winter

Quantification of dietary overlap with Ruzicka's Index of Quantitative Similarity (Sum Min Ci/Sum Max Ci)(100) (Ruzicka 1958), is presented in Table 10 for both winter and spring diets. Greatest overlap (37%) during winter occurred between cattle and sheep diets. Overlap between cattle and both native herbivores was merely 6%. The only other substantial overlaps were between sheep and jackrabbits (21%), and sheep and pronghorn (18%).

Spring

Spring diet overlaps increased in 67% of dietary relationships. Cattle and sheep diets again showed the greatest similarity (51%), with sheep and jackrabbit similarity (23%) following. Unlike winter, spring cattle and jackrabbit diets overlapped substantially (21%). Sheep and pronghorn similarity was reduced to 12%.

DISCUSSION

Diets

Cattle

The results of this study harmonize with studies similar in season and habitat. Smith et al. (1968) reported 98.4% of cattle diets in southern Nevada were composed of squirreltail grass, Great Basin wild rye (*Elymus cinereus*), and Indian ricegrass. Cook and Harris (1968), determining winter diets of cattle on desert shrub ranges of Utah, found that grass comprised only 56.7% of the diet. Important grasses were galleta grass and Indian ricegrass. Both winter and spring cattle diets in this study were strongly grass

dependent, 96% and 93% respectively, with Indian ricegrass, squirreltail grass, and galleta grass predominating.

A comparison of the relative similarity of cattle winter and spring diets with vegetation of the range sites shows cattle are graminoid specialists. Ruzicka's Index computed for similarity of cattle diet and habitat is 17.5% for winter and 12.7% for spring. This specialization substantially reduces dietary overlap with both native herbivores of this study.

Sheep

Comparison of the quantitative similarity of items in sheep diets with that of the habitat by Ruzicka's Index of Quantitative Similarity is 29.1% for winter and 21.4% for spring. This demonstrates the generalist foraging strategy of sheep. Sheep adaptation to the desert shrub range appears greater than cattle, and in this study, greater than either of the native herbivores. It is plausible that the intraspecific competition resulting from foraging in bands of nearly 2,000 forces an increased generalistic strategy upon the majority of the sheep as more choice dietary items are removed by preceding individuals in the band. Thus intraspecific competition may force the greater habitat and diet similarity observed.

Regardless of proximate cause, the generalist tendency observed here is in accord with the body of pertinate literature. Cook and Harris (1950) conducting winter utilization studies in the desert salt shrub type of Utah reported that percent of browse in the diet varied from 98.8% in early winter to 3.7% during spring "green up." Hutchings and Stewart (1953) noted a strong browse preference with grasses next and forbs in limited quantities. The winter diet was composed of

winterfat 35.1%, shadscale 17.6%, Indian ricegrass 14.1%, galleta grass 12.8%, sand dropseed 8.6%, and globemallow (Sphaeralcea grossulariaefolia) 4.4%. Cook and Harris (1968), following a 5 year study on southwestern Utah salt desert shrub ranges found browse constituted over 75% of sheep winter diets. Grass, although less utilized, was preferred over browse.

Pronghorn

The specialist strategy of pronghorns as compared to forage availability in the habitat was quantified according to Ruzicka's index as 6.9% during winter and 7.3% during the early spring. As noted previously, black sagebrush accounted for 93% and 83% of the winter and spring diets respectively.

The preponderance of browse, especially various species of sagebrush, in pronghorn diets has been widely documented (Mitchell and Smoliak 1971, Swartz and Nagy 1976, Bayless 1969, Smith and Malechek 1974). Smith et al. (1965) rated big sagebrush nearly three times more preferred than the next most frequently utilized item in pronghorn feeding trials at the DER. Severson and May (1967) listed fall and winter diets of big sagebrush, Douglas rabbitbrush (Chrysothamnus douglassii), and winterfat in the Red Desert of Wyoming. Beale and Smith (1970) investigated pronghorn winter and spring diets at the DER reporting high browse use and preference in winter with a trend towards greater forb use and preference in spring. Spring forb selection tripled over winter forb selection in pronghorn diets. Yoakum (1978) suggested spring forb availability may be critical to reproductive success.

Jackrabbits

Numerous studies have documented the wide variety of dietary habits of black-tailed jackrabbits. Jackrabbit diets appear to correlate to habitat and show substantial adaptation to numerous vegetation types (Flinders and Hansen 1972). Winter diets have been reported as predominately forbs and grasses (Sparks 1968), or shrubs (Hayden 1966, Currie and Goodwin 1966 , MacCracken and Hansen 1984). Jackrabbit winter diets at the DER conform to the later category. Spring diets reported consisted mostly of grasses (Currie and Goodwin 1966), or grasses and forbs (Westoby 1980, Uresk 1978). Spring diets in this study were strongly graminiferous.

On the DER study site habitat and diet similarity indices computed by Ruzicka's method were 15.5% for winter and 4.4% for spring. These indices show departure from the substantial correlation often reported in the literature. The extreme scarcity of jackrabbits on the study site, as previously mentioned, may have allowed greater and more pronounced selective expression by the few remaining individuals, resulting in decreased habitat and diet similarity.

Dietary Interactions

Partitioning

The degree of dietary partitioning differed, but not significantly, between winter and spring sampling periods. Similarity between diet and habitat was greater during winter when decreased forage quantity probably required each herbivore to utilize a resource base more similar to the habitat. In spite of this, the degree of dietary overlap between the herbivores was less during the winter and greater during the spring. Forage availability was also less during

the winter. Although the selection of different winter and spring study sites confounds the per unit forage increase from winter to spring, and spring growth was still incomplete at the time of sampling, available forage was 300% greater on the spring, as compared to the winter, study site. It is apparent that substantially more forage was available during the early spring than the winter study period.

A synthesis of the above trends supports the conclusion that dietary partitioning is greatest during the winter, the season of greatest resource scarcity. Increased forage in spring permitted a greater degree of dietary overlap without interspecific competition. The increase of available forage also permitted greater divergence of herbivore diets from the habitat.

Over the combined periods of use the degree of overlap between the two native herbivores is less than the overlap between the domestic herbivores. This probably results from evolutionary forces operating over time as the native species interacted, each establishing its own and increasingly unique niche. Such a partitioning strategy has the advantage of allowing larger populations of sympatric feeders to survive seasons of resource shortage.

Potential Competition

In an effort to identify dietary species most likely to become objects of realized competition, it should be noted that although the potential for competion between herbivores increases as the percent of a common forage species increases in the diets of two or more herbivores, this alone does not necessarily indicate that the species may be reasonably expected to be the object of realized competition.

Relative preference indices were combined with percent relative density of plant fragments in diets to identify the suite of forage species most likely to become the subject of critical competition between two or more of the herbivores. For this evaluation, plant species with preference indices previously described as suspect were omitted and only those preferred species which constitute a substantial portion (5% or more) of the diet of any herbivore were considered.

During winter grazing a suite of four common and substantially utilized species, Orizopsis hymenoides, Stipa comata, Eurotia lanata, and Artemisia nova, were identified as the most likely objects of realized competition between two or more of the herbivores. Cattle and sheep prefer and utilize substantial amounts of Orizopsis hymenoides and Stipa comata. Sheep and pronghorn prefer and utilize substantial amounts of Artemisia nova. Sheep and jackrabbits prefer and utilize substantial amounts of Eurotia lanata.

During early spring grazing one species, Orizopsis hymenoides, was identified as a reasonably likely object of realized competition. It is preferred and utilized in substantial amounts by cattle, sheep, and jackrabbits.

Possible Displacement

In the event competition is realized, the advantages of the broad resource base utilization strategy of sheep and jackrabbits is apparent. Cattle, grass dependent, may be adversely affected by competition with sheep in the event of grass shortage. Sheep, enjoying greater resiliency due to their widely varied diet, would simply be confined to a lesser portion of their customary broad

resource base, while cattle may be displaced.

Pronghorn may suffer similarly, though more severely than cattle, in competition with sheep. The mainstay of pronghorn diets is a single species, black sagebrush, which also constitutes 25% of sheep winter diets. In the event of realized competition for black sagebrush, the broader resource base used by sheep would largely insulate them from adverse effects while the specialist pronghorn, due to its extremely narrow resource base, would likely be severely affected, even eliminated, by competition with sheep.

Jackrabbits utilize a relatively broad resource base making them more resilient in the face of competition with other herbivores. Gross size disparity and mechanical differences, allowing jackrabbits to access and utilize extremely small plants unaccessible to larger herbivores, may increase their resiliency.

Is There Competition?

An important question suggested by the data is whether the observed winter partitioning of forage is obligatory, due to scramble competition, or facultative. Although the capacity, and perhaps propensity, towards dietary partitioning and maintenance on sub-optimal forage during times of resource shortage and competition is of obvious evolutionary value, application of the theory of consequential error (Belovski and Jordan 1981, Glander 1981, Orians 1981) suggests that over the long term, genetic fitness is sacrificed by individuals which consistently select sub-optimum forage during a season of nutritional stress, when better quality forage is available. The influence of varying forage quality, euphagia, and hedyphagia (Arnold and Dudzinski 1978) complicate the issue as does the fact that

half of the herbivores in the study are domestic and thus not subject to the full results of consequential error; however an explanation of the increase of forage availability, the increase of dietary overlap between the herbivores, and the decrease of diet-habitat similarity from winter to spring cannot rule out the possibility of realized forage competition during the winter.

RECOMMENDATIONS

Presently animal unit equivalents (AUEs) calculated from the metabolic liveweight (MBW) of a herbivore (Weight $kg^{0.75}$) compared to that of a mature cow (Cow weight $kg^{0.75}$ / herbivore weight $kg^{0.75}$) (Cordova et al. 1978), are often used in forage allocation decisions. All herbivores are compared uniformly on the basis of metabolic liveweight alone, which assumes identical dietary habits. This study, and many previous, convincingly refutes the identical diet assumption, and suggests several new methods, utilizing dietary habit information, by which forage demand and allocation may be more precisely calculated.

Forage Allocation by Dietary AUEs

Flinders and Conde (1980) recommended computation of AUEs by incorporating the degree of dietary overlap, calculated by Ruzicka's Index of Quantitative Similarity (Ruzicka 1958), with the ratio of herbivore metabolic liveweight, thereby producing a measure of equivalent forage selection. By the proposed system, for example, the number of sheep required to remove the same amount of forage of the same species composition as one cow is calculated as follows: ((Cow weight $kg^{0.75}$ / Sheep weight $kg^{0.75}$) / Proportion of dietary overlap). AUEs can thus be calculated for any herbivore in relation

to any other herbivore. The traditional cow unit need not, and often should not, be the sole basis of comparison.

The critical item in the proposed formula is the proportion of dietary overlap, the improper choice of which would be detrimental to both rangeland and herbivores. Two methods of computing the degree of dietary similarity by Ruzicka's index are discussed below.

Strict Seasonal Dietary Similarity AUEs

The first alternative is to utilize the dietary overlap calculated for each season by strict application of Ruzicka's Index of Quantitative Similarity. This approach permits the maximum amount of resource utilization. It enforces the amount of partitioning observed in winter and spring respectively. As previously noted, Table 10 shows percent winter and spring dietary similarity derived by strict application of Ruzicka's Index to data from each period.

Maximum Inter-Seasonal Dietary Similarity AUEs

The second alternative is a more forage conservative approach which utilizes the greatest possible degree of dietary similarity over the combined seasons of use. Given the possibility, explained above, that the more pronounced winter partitioning may result from actual competition and displacement, it may be considered unwise to calculate AUEs solely from this proportion, thereby imposing extreme winter partitioning and potentially subsistence diets on all herbivores. While partitioning intensifies when resource scarcity demands it, the interest of optimizing herbivore and rangeland sustained yields requires it not be imposed unnecessarily.

To reduce the probability of imposing subsistance diets, the conservative approach selects the season of maximum similarity of use for each plant species common in the diets of two or more herbivores and applies Ruzicka's formula to these data. This method uses the greatest observed degree of dietary overlap and thus computes AUEs in a way more likely to prevent over-use of forage species. This makes some allowance for competition which may otherwise result as different herbivores remove the same forage species during different seasons such that the dietary overlap is not detected within any single season. Results of the maximum inter-seasonal similarity alternative are presented in Table 11. The potential difference in AUEs created by selection of dietary proportions is illustrated by the comparisons of Table 12.

Recommended AUEs

Table 13 contains the number of herbivores per AUE calculated with strict seasonal dietary similarity. Table 14 contains the number of herbivores per AUE calculated with maximum inter-seasonal dietary similarity. It is contemplated that forage allocation using the AUEs presented in Table 14 will be most likely to prevent over-use of plant species.

Example Comparison of Dietary and Standard AUE Methods

The resulting differences in forage allocation by standard and dietary methods may be illustrated by the following hypothetical example. Assume after applying an allowable use factor of 50% for current year's production of all relevant forage species on unit 1, that 15,000 kg of forage are available in the 400 ha unit. Assume also during a 90 day period that resident populations of 20 pronghorn

and 30 jackrabbits use the unit, and that 2,000 sheep also graze the unit for 7 days. Given the forage demand by these herbivores, how many cattle may safely graze unit 1 for the 90 day period without exceeding the remaining allotted available forage? Table 15 evaluates the AUEs required by each herbivore based on the standard MBW approach and the dietary similarity approach. For simplicity, the amount of forage required by each herbivore is expressed as cattle-based AUEs. The table shows that in terms of equivalent forage selection, jackrabbits and pronghorn, because of their dietary disimilarity with cattle, actually utilize less than 5% of the cattle-based AUEs usually allotted to them by the standard MBW AUE method. Sheep utilize slightly more than half of the cattle-based AUEs usually allotted to them by the standard MBW AUE method. The additional cattle-based AUEs of forage remaining can be allotted to support more cattle on the unit. As Table 15 shows, the number of cattle which may safely graze the unit is 2.3 if the standard MBW AUE method is applied, but 26.1 if dietary similarity is considered as in the dietary AUE method. This illustrates the greater level of forage harvest achieved when dietary similarity is used to evaluate the amount of forage removed of the same species composition, rather than live weight alone.

Forage Allocation by Estimated Intake Rates

While dietary AUEs are preferable to AUEs computed from metabolic live weight, they still mask some of the effects of grazing on specific forage species. Because the proportion of dietary overlap is reduced to a single number by Ruzicka's index, specific use on any one forage species is not readily discernable. A strategy of estimating intake rates of each forage species by each herbivore predicts the

actual extent of utilization sustained by each forage species.

The total daily forage requirement for each herbivore may be reasonably estimated by the equation: Daily forage kg = 0.045 x (Herbivore weight kg $)^{0.75}$ (Giles 1978). In this way it is estimated that the daily forage intake per individual herbivore will be: cow, 4.426 kg; sheep, 0.884 kg; pronghorn, 0.782 kg; and jackrabbit, 0.097 kg. The total daily forage requirement multiplied by the percent composition of the diet produces the estimated daily amount of each plant species removed by each herbivore. All plant species constituting 5% or more of the diet of any herbivore are included in this operation, the results of which are presented in Tables 16 and 17 for winter and early spring respectively. Estimates of plants comprising less than 5% of the diet were considered so prone to experimental error that the information provided would be of questionable value and were therefore excluded from forage consumption totals. This approach accounts for 90% of cattle diets, 87% of sheep diets, 96% of pronghorn diets, and 79% of jackrabbit diets on unit 1, and for 88% of cattle diets, 76% of sheep diets, 90% of pronghorn diets, and 87% of jackrabbit diets on unit 2.

Hypothetical Application of Estimated Intake Method

An example of computing forage requirements for several species may be constructed by reference to the approximate demands by herbivores grazing unit 1 during winter. Following sheep grazing in mid December 1981, unit 1 was grazed for approximately 90 days by cattle, pronghorn, and jackrabbits. Since remaining previous year's production data were collected after winter sheep grazing, the following hypothetical problem closely parallels the actual situation

on unit 1 during most of the winter of 1981-82.

Assume the only herbivores foraging on unit 1 during the 90 day period are 10 cattle, 20 pronghorn, and 30 jackrabbits, and that unit 1 is 4 km^2. Winter daily forage intake is calculated for each herbivore for the 90 day period and compared to the extrapolated total remaining previous year's production for the entire unit to yield percent utilization. These data appear in Table 18. Examination of the results shows acceptable use levels (not greater than 50%) for seven of the nine key species. Note that production and availability of one apparently over-used species, Bromus tectorum, is probably greater than reported herein because of its propensity for growth whenever moisture and temperature permit. On unit 1, new growth was observed in early March. Percent utilization in a real situation would therefore probably be less than reported in the hypothetical example.

In the manner illustrated by this example, forage intake for any combination or number of herbivores may be determined by species specific forage requirements computed from dietary preferences. This approach most fully describes the actual demand exerted by grazing herbivores on the forage resource and most accurately identifies potential over-use.

CONCLUSION

The dietary habits of cattle, sheep, pronghorn, and black-tailed jackrabbits were examined by microhistological methods in the winter and early spring on Allotment 3 of the DER in southwestern Utah. Application of Ruzicka's Index of Quantitative Similarity to dietary data showed greater dietary similarity during both seasons between

domestic herbivores than native herbivores. Dietary partitioning of all herbivores was greater during the winter, the season of greatest forage scarcity, and appeared to moderate as available forage increased in early spring.

Evaluation of preference-availability data and vegetation sampling results suggests the greatest winter competition potential exists between cattle and sheep for Orizopsis hymenoides, between sheep and pronghorn for Artemisia nova, and between sheep and jackrabbits for Eurotia lanata. The greatest spring competition potential exists between cattle, sheep, and jackrabbits for Orizopsis hymenoides.

Based on the observed dietary similarities between the herbivores two new methods of forage allocation, dietary AUEs and estimated forage intake rates, are developed. The dietary AUE method emphasizes percent similarity of the total diets and the removal of the same amount of forage of the same species composition, while the estimated forage intake method emphasizes the daily amount of each forage species utilized by each herbivore.

Application of the principles illustrated herein will enhance range grazing returns by recognizing and capitalizing on inherent herbivore dietary differences and allocating forage resources accordingly. It is contemplated that the dietary approach will more accurately assess herbivore demands on specific forage species and reduce the possibility of range over-use.

LITERATURE CITED

Arnold, G.W., and M.L. Dudzinski. 1978. Ethology of free-ranging domestic animals. Elsevier Sci. Pub. Co., New York.

Bayless, S.R. 1969. Winter food habits, range use, and home range of antelope in Montana. J. Wildl. Manage. 33:538-551.

Beale, D.M., and A.D. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. J. Wildl. Manage. 34:570-582.

Belovsky, G.E., and P.A. Jordan. 1981. Sodium dynamics and adaptations of a moose population. J. Mamm. 62:613-621.

Buchner, H. K. 1950. Life history, ecology, and range use of the pronghorned antelope in Trans-pecos Texas. Am. Midl. Nat. 45:257-354.

Clary, W.P., and R.C. Holmgren. 1981. Observations of pronghorn distribution in relation to sheep grazing on the Desert Experimental Range. Paper given at Wildlife-Livestock Relationships Symposium, April 1981: Coerud'Alene, Idaho.

Cochran, W.G. 1977. Sampling techniques. Third edition. Wiley Publishing. New York.

Cock, M.J.W. 1978. The assessment of preference. J. Anim. Ecol. 47:805-816.

Cook, C.W., and L.E. Harris. 1968. Nutritive value of seasonal ranges. Utah Agr. Expt. Sta. Bull. 472.

Cook, C.W., and L.E. Harris. 1950. The nutritive content of the grazing sheep's diet on summer and winter ranges of Utah. Utah Agr. Expt. Sta. Bull. 342.

Cordova, F.J., J.D. Wallace, and R.D. Pieper. 1978. Forage intake by grazing livestock: a review. J. Range Manage. 31:430-438.

Currie, P.O., and D.L. Goodwin. 1966. Consumption of forage by black-tailed jackrabbits on salt-desert ranges of Utah. J. Wildl. Manage. 30:304-311.

Ellis, J.E., J.A. Wiens, C.F. Rodell, and J.C. Anway. 1976. A conceptual model of diet selection as an ecosystem process. J. Theor. Biol. 60:93-108.

Flinders, J.T., and L. L. Conde. 1980. An alternate method of calculating animal unit equivalents helps ranchers and wildlife. 33rd Annual Meeting Society for Range Manage., San Diego, p. 48 Abstracts.

Flinders, J.T., and R.M. Hansen. 1972. Diets and habitats of jackrabbits in northeastern Colorado. Range Sci. Dep. Sci. Ser., Colorado State Univ., No. 12.

Fracker, S.B., and J.A. Brischle. 1944. Measuring the local distribution of Ribes. Ecology 25:283-303.

Giles, R.H. 1978. Wildlife management. Freeman and Co. San Francisco.

Glander, K.E. 1981. Feeding patterns in mantled howling monkeys, p. 231 to 257. In: A. C. Kamil and T. D. Sargent (eds.) Foraging behavior: ecological, ethological and psychological approaches. Garland STPM Press, New York.

Green, J.S., and J.T. Flinders. 1980. Habitat and dietary relationships of the pygmy rabbit. J. Range Manage. 33:136-142.

Hansen, R.M., T.M. Foppe, M.B. Gilbert, R.C. Clark, and H.W. Reynolds. 1978. The microhistological analysis of feces as an estimator of herbivore dietary. Composition Analysis Laboratory, Colorado State Univ.

Hansen, R.M., and J.T. Flinders. 1969. Food habits of North American hares. Range Sci. Dep. Sci. Ser., Colorado State Univ., No. 1.

Hayden, P. 1966. Food habits of black-tailed jackrabbits in southern Nevada. J. Mamm. 47:24-26.

Holechek, J.L., and M. Vavra. 1981. The effect of slide and frequency observation numbers on the precision of microhistological analysis. J. Range Manage. 34:337-338.

Holmgren, R.C. 1974. The desert experimental range: description, history and program. In: Arid Shrublands - Proceedings of the Third Workshop of the United States/Australia Rangelands Panel. Tucson, March 26-April 5, 1973, pp. 18-22.

Holmgren, R.C., and S. F. Brewster. 1972. Distribution of organic matter reserve in a desert shrub community. USDA For. Serv. Res. Pap. INT-130 IF and RES, Ogden.

Holmgren, R.C., and S.S. Hutchings. 1972. Salt desert shrub response to grazing use. In: Wildland Shrubs and Their Biology and Utilization. Proceedings of an International Symposium. USU, Logan, July 1971. USFS Gen. Tech. Rep. INT-I, 1972, pp. 153-165.

Hoover, R.L., C.E. Till, and S. Ogilvie. 1959. The antelope of Colorado. Colorado Dep. of Game and Fish Tech. Bull. No.4, 110 pp.

Hutchings, S.S., and G. Stewart. 1953. Increasing forage uields and sheep production on Intermountain winter ranges. U.S. Dep. Agric. Circ. 925, 63 pp.

Krueger, W.C. 1972. Evaluating animal forage preference. J. Range Manage. 25:471-475.

Loehle, C., and L.R. Rittenhouse. 1982. An analysis of forage preference indices. J. Range Manage. 35:316-319.

MacCracken, J.G., and R.M. Hansen. 1984. Seasonal foods of blacktail jackrabbits and nuttall cottontails in southeastern Idaho. J. Range Manage. 37:256-259.

Mitchell, G.J., and S. Smoliak. 1971. Pronghorn antelope range characteristics and food habits in Alberta. J. Wildl. Manage. 35:238-250.

Orians, G.H. 1981. Foraging behavior and the evolution of discriminatory abilities, p. 289 to 310. In: A.C. Kamil and T.D. Sargent (eds.) Foraging behavior: ecological, ethological and psychological approaches. Garland STPM Press, New York.

Pechanec, J.F., and G.D. Pickford. 1937. A weight estimate for the determination of range or pasture production. J. Amer. Soc. Agron. 29:894-904.

Ruzicka, M. 1958. Anwendung Mathematisch - Statisticher Methoden in Der Geobotanik (Synthetische Bearbeitung von Aufnahmen). Biologia, Bratisl. 13:647-661.

Severson, K.E., and M. May. 1967. Food preferences of antelope and domestic sheep in Wyoming's Red Desert. J. Range Manage 20:21-25.

Smith, A.D., D.M. Beale, and D.D. Doell. 1965. Browse preferences of pronghorn antelope in southwestern Utah. Thirteenth N. Am. Wildl. and Nat. Resour. Conf. Trans. Wash. D.C.: Wildl. Manage. Inst.

Smith, T.M., A.L. Lesperance, V.R. Bohman, R.A. Brechbill, and K.W. Brown. 1968. Intake and digestibility of forages grazed by cattle on a southern Nevada range. Proc. West. Sec. Am. Soc. Animal Sci. Vol. 19:227-282.

Smith, A.D., and J.C. Malechek. 1974. Nutritional quality of summer diets of pronghorn antelope in Utah. J. Wildl. Manage. 38:792-798.

Sparks, D.R. 1968. Diets of black-tailed jackrabbits on sandhill rangeland in Colorado. J. Range Manage. 21:203-208.

Sparks, D.R., and J.C. Malechek. 1968. Estimating percentage dry weight in diets using a microscopic technique. J. Range Manage. 21:264-265.

Swartz, C.C., and J. C. Nagy. 1976. Pronghorn diets relative to forage availability in northeastern Colorado. J. Wildl. Manage. 40:469-478.

Tadmor, N.H., A. Briegher, I. Noy-Meir, R.W. Benjamin, and E. Eyal. 1975. An evaluation of the calibrated weight-estimate methods for measuring production in annual vegetation. J. Range Manage. 28:65-69.

Uresk, D.W. 1978. Diets of the blacktail hare in steppe vegetation. J. Range Manage. 31:439-442.

Uresk, D.W., R.O. Gilbert, and W.H. Rickard. 1977. Sampling big sagebrush for phytomass. J. Range Manage. 30:311-314.

Vavra, M., R.W. Rice, and R.M. Hansen. 1978. A comparison of esophageal fistula and fecal material to determine steer diets. J. Range Manage. 31:11-13.

Westoby, M. 1980. Blacktailed jackrabbit diets in Curlew Valley, northern Utah. J. Wildl. Manage. 44:942-948.

Yoakum, J.D. 1978. Pronghorn. In: J.L. Schmidt and D.L. Gilbert (eds.) Big Game of North America Ecology and Management. Stackpole Books, Harrisburg. 494 pp.

Table 1. Regression equations, degrees of freedom, and r^2 values used to determine dry weight of remaining previous year's shrub production (y) where x variables are as follows: L = longest diameter of canopy; W = longest diameter of canopy at right angles to dimension L; D = average canopy depth; H = average height; and P = occular estimate of percent live portion of the canopy.

Shrub species	df	Regression equation	r^2
Artemisia bigelovii	14	-7.3+.468L+.105W-.324H+.43D+6.86P	76.8
Artemisia frigida	22	.5+.003(((.5L*.5W)3.14)D+.00001P)	90.5
Artemisia nova	18	3.2+.0025(((.5L*.5W)3.14)D(.01P))	97.5
Artemisia spinescens	28	-.01+.014((((.5L*.5W)3.14)D).01P)	92.9
Atriplex confertifolia	14	-27.7+.214L+.392W+.08H+.414D+.24P	86.7
Chrysothamnus greenei	19	-2.43-.025L+.124W+.144H-.25D+.06P	84.0
Ephedra nevadensis and *viridis*	13	-124+.09(.5L*.5W)-2.1H+4.4D+2.26P	92.0
Eurotia lanata	18	.477+.001((((.5L*.5W)3.14)D).01P)	92.6
Forsellesia nevadensis	12	-9.78+.124L-.032W+.3H+.005D+.125P	83.1
Gutierrezia sarothrae	19	-15.6+.51L-.222W+.69H-.002D+.046P	86.1
Haplopappus cervinus	16	-11.1+.76L+.085W-.345H-.51D+.064P	81.2
Symphoricarpos longiflorus	3	.243+.000274((.5L*.5W)P)	97.1
Tetradymia glabrata and *nuttallii*	7	-12.2+.138L+2.72D	80.7

* Correlation of each equation is significant at $p<0.01$.

Table 2. Mean and 90% confidence intervals for previous year's growth of vegetation on unit 1, allotment 3, DER.

Plant species	Mean (kg/ha)	90% CI (kg/ha)
Grasses:		
Aristeda purpurea	0.28	0.12
Bouteloua gracilis	5.36	2.35
Bromus tectorum	0.04	0.04
Hilaria jamesii	1.74	1.30
Oryzopsis hymenoides	11.72	2.56
Sitanion hystrix	2.78	0.92
Sporobolus cryptandrus	0.50	0.22
Stipa comata	5.03	2.11
Total grasses:	27.45	
Forbs:		
Astragalus spp.	*	*
Calochortus flexuosus	0.01	0.01
Castilleja chromosa	*	*
Cryptantha spp.	0.32	0.17
Cymopterus basalticus	*	*
Descurainia pinnata	*	*
Eriogonum shockleyi	1.34	0.30
Gilia spp.	0.01	0.01
Halogeton glomeratus	0.32	0.35
Haplopappus spp.	0.09	0.07
Hymenopappus filifolia	0.07	0.06
Lappula redowskii	0.31	0.20
Lepidium spp.	0.06	0.05
Macheranthera canescens	0.01	0.01
Macheranthera grindelioides	0.27	0.28
Oenothera caespitosa	0.01	0.01
Petradoria pumilia	0.41	0.51
Ranunculus juniperinus	0.05	0.07
Salsola iberica	0.15	0.17
Sphaeralcea caespitosa	0.01	0.01
Total forbs:	3.44	
Shrubs:		
Artemisia bigelovii	1.29	0.57
Artemisia frigida	0.22	0.17
Artemisia nova	10.07	1.75
Artemisia spinescens	0.18	0.05
Atriplex confertifolia	8.89	0.99
Cercocarpus intricatus	0.56	0.46
Chrysothamnus greenei	1.62	0.33
Ephedra nevadensis	1.94	0.32
Ephedra viridis	0.40	0.16
Eurotia lanata	1.01	0.22
Forsellesia nevadensis	1.84	0.73
Gutierrezia sarothrae	23.34	1.88
Haplopappus cervinus	1.86	0.82
Juniperus osteosperma	*	*
Leptodactylon pungens	0.07	0.02

Prunus fasiculata	0.10	0.08
Salva carnosa	0.11	0.06
Symphoricarpos longiflorus	0.13	0.08
Tetradymia nuttallii	0.38	0.11
Yucca harrimaniae	0.04	0.02
Total shrubs:	54.01	
Total production:	84.90	

* less than 0.01 kg/ha.

Table 3. Mean and 90% confidence intervals for current annual growth of vegetation on unit 2, allotment 3, DER.

Plant Species	Mean (kg/ha)	90% CI (kg/ha)
Grasses:		
Agropyron spicatum	3.32	2.35
Aristeda purpurea	1.04	0.53
Bouteloua gracilis	2.35	0.88
Bromus tectorum	0.25	0.20
Erioneuron pilosum	0.40	0.25
Erioneuron pulchellum	0.05	0.06
Hilaria jamesii	6.43	1.68
Oryzopsis hymenoides	9.74	2.83
Poa secunda	0.25	0.17
Sitanion hystrix	0.07	0.04
Sporobolus cryptandrus	9.30	3.62
Stipa arida	3.54	1.33
Stipa comata	12.77	7.29
Total grasses:	49.51	
Forbs:		
Alium nevadensis	0.01	0.01
Arabis lignifera	0.09	0.06
Arenaria kingii	0.10	0.09
Astragalus spp.	0.08	0.06
Castilleja chromosa	0.02	0.03
Cryptantha spp.	0.68	0.48
Cymopterus basalticus	0.03	0.02
Draba rectifracta	0.08	0.04
Encelopsis nudicaulis	0.77	0.27
Eriogonum eremicum	1.25	0.49
Eriogonum ovalifolium	0.11	0.09
Eriogonum shockleyi	0.54	0.38
Erysimum asperum	0.03	0.03
Gilia spp.	0.02	0.03
Haplopappus spp.	1.16	0.52
Hymenopappus filifolius	0.15	0.07
Hymenoxys acaulis	0.12	0.09
Lappula redowskii	0.08	0.05
Lepidium spp.	0.06	0.03
Leucene ericoides	0.02	0.02
Lomatium grayi	0.31	0.21
Macheranthera canescens	0.08	0.10
Macheranthera grindelioides	0.55	0.23
Oenothera caespitosa	0.18	0.06
Penstemon spp.	0.01	0.01
Petradoria pumilia	4.86	2.10
Phacelia corrugata	0.04	0.02
Phlox longifolia	0.08	0.04
Phlox muscoides	0.07	0.05
Ranunculus juniperinus	0.09	0.11
Sphaeralcea caespitosa	0.39	0.11
Sphaeralcea grossulariifolia	0.10	0.05
Total forbs:	12.16	

Shrubs:		
Artemisia bigelovii	2.80	2.47
Artemisia frigida	1.05	0.93
Artemisia nova	19.25	11.09
Artemisia spinescens	0.34	0.28
Atriplex confertifolia	42.75	18.60
Brickellia oblongifolia	1.03	1.03
Cercocarpus intricatus	5.55	7.70
Chrysothamnus greenei	5.10	3.57
Cowania mexicana	0.19	0.27
Ephedra nevadensis	46.50	23.74
Ephedra viridis	6.10	5.60
Eurotia lanata	0.09	0.08
Forsellesia nevadensis	0.78	1.08
Gutierrezia sarothrae	36.10	14.75
Haplopappus cervinus	4.10	3.80
Leptodactylon pungens	0.91	1.26
Prunus fasiculata	0.03	0.03
Symphoricarpos longiflorus	0.85	0.84
Tetradymia glabrata	0.59	0.84
Tetradymia nuttallii	8.15	7.69
Yucca harrimaniae	2.70	3.71
Total shrubs:	182.26	
Total production:	243.93	

Table 4. Mean % relative density of plant fragments found in winter diets of cattle, sheep, pronghorn, and jackrabbits in unit 1.

Plant Species	Cattle	Sheep	Prnghrn	Jckrbbt
Grasses and sedges:				
Bouteloua gracilis	1	1	*	*
Bromus tectorum	*	*	*	5
Carex spp.	3	0	0	0
Hilaria jamesii	3	4	*	*
Oryzopsis hymenoides	59	29	*	3
Poa secunda	*	2	*	*
Sitanion hystrix	11	3	*	1
Sporobolus cryptandrus	3	2	*	0
Stipa comata	16	12	*	1
Total (11 species)	96	53	1	10
Forbs:				
Arenaria kingii	0	*	0	2
Castilleja chromosa	*	*	*	1
Cryptantha spp.	*	*	0	1
Macheranthera grindelioides	0	3	3	15
Petradoria pumilia	*	1	0	3
Phlox musciodes	0	*	0	1
Sphaeralcea grosulariafolia	*	*	*	*
Unknown forb	0	0	0	1
Other	0	1	*	2
Total (18 species)	*	5	3	26
Shrubs:				
Artemisia frigida	0	*	*	2
Artemisia nova	0	25	93	8
Artemisia spinescens	0	*	*	1
Atriplex confertifolia	2	4	*	7
Cercocarpus intricatus	0	0	1	2
Ephedra nevadensis	0	1	*	1
Eurotia lanata	2	11	*	21
Forsellesia nevadensis	0	*	*	18
Gutierrezia sarothrae	*	*	*	*
Leptodactylon pungens	0	*	0	2
Prunus fasiculata	0	*	1	1
Other	0	1	1	1
Total (16 species)	4	42	96	64

* less than 1% relative density.

Table 5. Mean % relative density of plant fragments found in early spring diets of cattle, sheep, pronghorn, and jackrabbits in unit 2.

Plant Species	Cattle	Sheep	Prnghrn	Jckrbbt
Grasses:				
Bouteloua gracilis	1	*	*	*
Bromus tectorum	1	*	1	54
Hilaria jamesii	4	4	*	*
Oryzopsis hymenoides	60	44	1	25
Poa secunda	2	1	1	2
Sitanion hystrix	3	3	*	2
Sporobolus cryptandrus	12	3	0	0
Stipa comata	10	6	*	1
Other	0	1	0	*
Total (10 species)	93	62	3	84
Forbs:				
Arabis lignifera	0	*	1	0
Castilleja chromosa	*	2	*	*
Cryptantha spp.	0	1	*	0
Erysimum asperum	0	*	0	*
Macheranthera grindelioides	0	2	5	4
Oenothera caespitosa	0	*	0	2
Petradoria pumilia	*	2	2	*
Sphaeralcea grosulariafolia	*	1	1	3
Other	0	2	1	3
Total (34 species)	*	10	10	12
Shrubs:				
Artemisia nova	1	12	83	*
Artemisia spinescens	0	1	*	0
Atriplex confertifolia	4	9	*	3
Cercocarpus intricatus	0	*	1	*
Ephedra nevadensis	*	1	0	0
Eurotia lanata	1	3	*	*
Forsellesia nevadensis	0	*	1	*
Gutierrezia sarothrae	1	*	1	0
Prunus fasiculata	0	*	*	*
Other	0	2	1	1
Total (18 species)	7	28	87	4

* less than 1% relative density.

Table 6. Forage ratio preference indices (Krueger 1972) for plants found in winter diets of cattle, sheep, pronghorn, and jackrabbits in unit 1.

Plant Species	Cattle	Sheep	Prnghrn	Jckrbbt
Grasses and sedges:				
Bouteloua gracilis	0.2	0.2	0	0
Bromus tectorum	0	0	0	120.5
Carex spp.	*	0	0	0
Hilaria jamesii	1.5	2.0	0	0
Oryzopsis hymenoides	4.3	2.1	0	0.2
Poa secunda	0	*	0	0
Sitanion hystrix	3.5	0.9	0	0.3
Sporobolus cryptandrus	5.1	3.4	0	0
Stipa comata	2.7	2.0	0	0.2
Forbs:				
Arenaria kingii	0	0	0	*
Castilleja chromosa	0	0	0	400.0
Cryptantha spp.	0	0	0	2.7
Macheranthera grindelioides	0	9.5	9.5	47.6
Petradoria pumilia	0	2.1	0	6.3
Phlox musciodes	0	0	0	*
Shrubs:				
Artemisia frigida	0	0	0	7.9
Artemisia nova	0	2.1	7.9	0.7
Artemisia spinescens	0	0	0	4.7
Atriplex confertifolia	0.2	0.4	0	0.7
Cercocarpus intricatus	0	0	1.5	3.0
Ephedra nevadensis	0	0.4	0	0.4
Eurotia lanata	1.7	9.3	0	17.7
Forsellesia nevadensis	0	0	0	8.3
Leptodactylon pungens	0	0	0	25.2
Prunus fasiculata	0	0	8.7	8.7

* Species not encountered in production sampling.

Table 7. Forage ratio preference indices (Krueger 1972) for plants found in early spring diets of cattle, sheep, pronghorn, and jackrabbits in unit 2.

Plant Species	Cattle	Sheep	Prnghrn	Jckrbbt
Grasses:				
Bouteloua gracilis	1.0	0	0	0
Bromus tectorum	9.8	0	9.8	530.5
Hilaria jamesii	1.5	1.5	0	0
Oryzopsis hymenoides	15.3	11.2	0.3	6.4
Poa secunda	19.6	9.8	9.8	19.6
Sitanion hystrix	114.9	114.9	0	76.6
Sporobolus cryptandrus	3.2	0.8	0	0
Stipa comata	1.9	1.2	0	0.2
Forbs:				
Arabis lignifera	0	0	28.8	0
Castilleja chromosa	0	259.7	0	0
Cryptantha spp.	0	3.6	0	0
Erysimum asperum	0	0	0	0
Macheranthera grindelioides	0	9.1	22.7	18.2
Oenothera caespitosa	0	0	0	27.2
Petradoria pumilia	0	1.0	1.0	0
Sphaeralcea grosulariafolia	0	25.2	25.2	75.6
Shrubs:				
Artemisia nova	0.1	1.6	10.7	0
Artemisia spinescens	0	7.4	0	0
Atriplex confertifolia	0.2	0.5	0	0.2
Cercocarpus intricatus	0	0	0.4	0
Ephedra nevadensis	0	0.1	0	0
Eurotia lanata	28.6	85.7	0	0
Forsellesia nevadensis	0	0	3.2	0
Gutierrezia sarothrae	0.1	0	0.1	0
Prunus fasiculata	0	0	0	0

Table 8. Relative preference based on preference-availability index of Loehle and Rittenhouse (1982) after Ellis et al. (1976) for plants found in winter diets of cattle, sheep, pronghorn, and jackrabbits in unit 1.

Plant Species	Cattle	Sheep	Prnghrn	Jckrbbt
Grasses and sedges:				
Bouteloua gracilis	0.01	0.01	0	0
Bromus tectorum	0	0	0	0.18
Carex spp.	*	0	0	0
Hilaria jamesii	0.08	0.06	0	0
Oryzopsis hymenoides	0.22	0.06	0	0.00
Poa secunda	0	*	0	0
Sitanion hystrix	0.18	0.03	0	0.00
Sporobolus cryptandrus	0.26	0.10	0	0
Stipa comata	0.14	0.06	0	0.00
Forbs:				
Arenaria kingii	0	0	0	*
Castilleja chromosa	0	0	0	0.61
Cryptantha spp.	0	0	0	0.00
Macheranthera grindelioides	0	0.28	0.34	0.07
Petradoria pumilia	0	0.06	0	0.01
Phlox musciodes	0	0	0	*
Shrubs:				
Artemisia frigida	0	0	0	0.01
Artemisia nova	0	0.06	0.29	0.00
Artemisia spinescens	0	0	0	0.01
Atriplex confertifolia	0.01	0.01	0	0.00
Cercocarpus intricatus	0	0	0.05	0.00
Ephedra nevadensis	0	0.01	0	0.00
Eurotia lanata	0.09	0.27	0	0.03
Forsellesia nevadensis	0	0	0	0.01
Leptodactylon pungens	0	0	0	0.04
Prunus fasiculata	0	0	0.32	0.01

* Species not encountered in production sampling.

Table 9. Relative preference based on preference-availability indices of Loehle and Rittenhouse (1982) after Ellis et al. (1976) for plants found in early spring diets of cattle, sheep, pronghorn, and jackrabbits in unit 2.

Plant Species	Cattle	Sheep	Prnghrn	Jckrbbt
Grasses:				
Bouteloua gracilis	0.01	0	0	0
Bromus tectorum	0.05	0	0.09	0.70
Hilaria jamesii	0.01	0.00	0	0
Oryzopsis hymenoides	0.08	0.02	0.00	0.01
Poa secunda	0.10	0.02	0.09	0.03
Sitanion hystrix	0.59	0.22	0	0.10
Sporobolus cryptandrus	0.02	0.00	0	0
Stipa comata	0.01	0.00	0	0.00
Forbs:				
Arabis lignifera	0	0	0.26	0
Castilleja chromosa	0	0.49	0	0
Cryptantha spp.	0	0.01	0	0
Erysimum asperum	0	0	0	0
Macheranthera grindelioides	0	0.02	0.20	0.02
Oenothera canescens	0	0	0	0.04
Petradoria pumilia	0	0.00	0.01	0
Sphaeralcea grosulariafolia	0	0.05	0.23	0.10
Shrubs:				
Artemisia nova	0.00	0.00	0.10	0
Artemisia spinescens	0	0.01	0	0
Atriplex confertifolia	0.00	0.00	0	0.00
Cercocarpus intricatus	0	0	0.00	0
Ephedra nevadensis	0	0.00	0	0
Eurotia lanata	0.15	0.16	0	0
Forsellesia nevadensis	0	0	0.03	0
Gutierrezia sarothrae	0.00	0	0.00	0
Prunus fasiculata	0	0	0	0

Table 10. Percent winter and early spring dietary overlap of cattle, sheep, pronghorns, and jackrabbits on allotment 3, DER by strict seasonal application of Ruzicka's (1958) Index of Quantitative Similarity.

	Winter			Early Spring		
	Sheep	Pronghorn	Jackrabbit	Sheep	Pronghorn	Jackrabbit
Cattle	37	1	5	51	3	21
Sheep		18	21		12	23
Pronghorn			8			5

Table 11. Maximum inter-seasonal percent dietary similarity between cattle, sheep, pronghorn antelope, and black-tailed jackrabbits on allotment 3 DER by Ruzicka's (1958) Index of Quantitative Similarity applied to combined winter and spring diets.

	Sheep	Pronghorn	Jackrabbits
Cattle	62	3	33
Sheep		21	44
Pronghorn			14

Table 12. Comparison of standard number of cattle, sheep, pronghorn, and jackrabbits per animal unit equivalent* with numbers of animals calculated from strict seasonal similarity and maximum inter-seasonal similarity of diets for allotment 3, DER.

Herbivore	Standard MBW AUEs	Winter Dietary AUEs	Spring Dietary AUEs	Max. Inter-seasonal dietary AUEs
Cattle	1.0	1.0	1.0	1.0
Sheep	5.0	13.5	9.8	8.1
Pronghorn	5.6	560.0	186.7	186.7
Jackrabbit	45.4	908.0	216.4	137.7

* Computed from degree of dietary similarity and liveweights as follows: cow, 454 kg; sheep, 53 kg; pronghorn, 45 kg; jackrabbit, 2.8 kg.

Table 13. Number of cattle, sheep, pronghorn, and jackrabbits required to remove equivalent amount of forage of same species composition on allotment 3, DER (calculated from strict seasonal similarity of diets).

Herbivore Unit	Number of Animals Per Herbivore Unit							
	Winter				Early Spring			
	Cows	Sheep	Prnghn	Jckrbt	Cows	Sheep	Prnghn	Jckrbt
Cattle	1.00	13.53	566.09	908.77	1.00	9.82	188.70	216.37
Sheep	0.54	1.00	6.28	43.21	0.39	1.00	9.42	39.46
Prnghn	17.67	4.91	1.00	100.33	5.89	7.37	1.00	160.54
Jckrbt	0.44	0.52	1.56	1.00	0.10	0.48	2.49	1.00

Table 14. Number of cattle, sheep, pronghorn, and jackrabbits required to remove equivalent amount of forage of same species composition on allotment 3, DER (calculated from maximum inter-seasonal similarity of diets).

Herbivore Unit	Number of Animals Per Herbivore Unit			
	Cattle	Sheep	Pronghorn	Jackrabbit
Cattle	1.00	8.08	188.70	137.69
Sheep	0.32	1.00	5.38	20.62
Pronghorn	5.89	4.21	1.00	57.33
Jackrabbit	0.07	0.25	0.89	1.00

Table 15. Example comparison of winter forage allocation by standard MBW AUEs and winter dietary AUES for concurrent grazing periods of 90 days for cattle, pronghorn, and jackrabbits, and 7 days for sheep on allotment 3, DER. Total cattle-based AUEs are 3,389.1.

	Allocation System	Herbivore Species			
		Cattle	Sheep	Prnghrn	Jckrbbt
Number of Herbivores	Standard MBW AUEs	2.3	2,000.0	20.0	30.0
	Winter Diet AUEs	26.1	2,000.0	20.0	30.0
Number of Cattle AUEs Required	Standard MBW AUEs	208.2	2,800.0	321.4	59.5
	Winter Diet AUEs	2,345.9	1,037.0	3.2	3.0

Table 16. Estimated winter daily forage consumption of 9 key plant species in kg dry weight per individual cow, sheep, pronghorn, or jackrabbit on unit 1, allotment 3, DER.

Plant Species	Cow	Sheep	Prnghrn	Jckrbbt
Bromus tectorum	0.00000	0.00000	0.00000	0.00487
Orizopsis hymenoides	2.61130	0.25634	0.00000	0.00292
Sitanion hystrix	0.48685	0.02652	0.00000	0.00097
Stipa comata	0.70815	0.10607	0.00000	0.00097
Macheranthera grindeliodes	0.00000	0.02652	0.02346	0.01461
Artemisia nova	0.00000	0.22098	0.72712	0.00779
Atriplex confertifolia	0.08852	0.03536	0.00000	0.00682
Eurotia lanata	0.08852	0.09723	0.00000	0.02046
Forsellesia nevadensis	0.00000	0.00000	0.00000	0.01753
Total	3.98330	0.76902	0.75057	0.07695

Table 17. Estimated early spring daily forage consumption of 7 key plant species in kg dry weight per individual cow, sheep, pronghorn, or jackrabbit on unit 2, allotment 3, DER.

Plant Species	Cow	Sheep	Prnghrn	Jckrbbt
Bromus tectorum	0.04426	0.00000	0.00781	0.05260
Orizopsis hymenoides	2.65554	0.38892	0.00781	0.02435
Sporobolus cryptandrus	0.53111	0.02652	0.00000	0.00000
Stipa comata	0.44259	0.05303	0.00000	0.00097
Macheranthera grindeliodes	0.00000	0.01768	0.03909	0.00390
Artemisia nova	0.00443	0.10607	0.64889	0.00000
Atriplex confertifolia	0.17704	0.07955	0.00000	0.00292
Total	3.85497	0.67177	0.70360	0.08474

Table 18. Example of evaluating forage production, percent utilization and winter forage requirements of 10 cattle, 20 pronghorn, and 30 jackrabbits for 90 days based on 9 key plant species on unit 1, allotment 3, DER.

Plant Species	Total Available Production (kg/400 ha)	Total Forage Demand (kg)	Percent Utilization
Bromus tectorum	16.0	13.2	82.2
Orizopsis hymenoides	4688.0	2358.1	50.3
Sitanion hystrix	1112.0	440.8	39.6
Stipa comata	2012.0	640.0	31.8
Macheranthera grindeliodes	108.0	81.7	75.6
Artemisia nova	4028.0	1329.8	33.0
Atriplex confertifolia	3556.0	98.1	2.8
Eurotia lanata	404.0	134.9	33.4
Forsellesia nevadensis	736.0	47.3	6.4